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A Novel Method of Differential Protection for Power Transformer

Nidhi Reddiwar¹, Dr. Harikumar Naidu²

PG Student [IPS], Dept. of EE, Tulsiramji Gaikwad Patil College Engineering, Nagpur, Maharashtra, India¹

HoD, Dept. of EE, Tulsiramji Gaikwad Patil College Engineering, Nagpur, Maharashtra, India²

ABSTRACT: The protection of power transformer is carried out by using unit differential relaying scheme. This protective scheme should operate only for internal faults in the transformer but not for the external fault. Also, this protective scheme should not operate for the inrush current in the transformer which occurs while energizing the transformer under no load condition. These currents are high in magnitude but remains for less time. These current causes protective relay mal-operation and reduces power quality on the system. So, the protective scheme should differentiate between inrush current and fault current. For this purpose, Fast Fourier transform based logic technique is used for the protection of transformer. Operation of Digital differential relay is simulated in Matlab. Different cases have considered for simulation of operation of differential relay.

KEYWORDS: Digital Protection, Differential Protection, Digita Differential Relay.

I. INTRODUCTION

Transformer is an important, essential and costlier element of electrical power system. So, the protection of transformer have the same importance. For the protection of transformer, digital differential protection scheme is applied in which terminal currents are used. In transformers, abnormal conditions like faults are divided into two categories:-1) Internal 2) External. Problems like short duration overloading, short circuit external to transformer, etc are included in external faults. Internal faults are grouped into three categories:-1) Incipient fault 2) Terminal faults 3) Winding faults. Both Internal and External faults can cause damage to the transformer. For external fault, protection scheme is used in the line and for internal faults, various protection schemes such as over current relay, gas actuated i.e. buchholz relay, restricted earth fault relay and percentage differential relay have been adopted. Protection scheme selected is depend upon the type of fault and also upon the type, size, rating and importance of the transformer being protected. In internal faults, terminal as well as winding faults are serious in nature. Unbalance of voltage or current can be occurred at the terminals when these faults are detected. These faults can cause immediate damage to the transformer. Incipient faults are initially minor in nature and of no immediate hazard but can turn into major faults if are not attended and cause damage to the transformer. When an abnormal condition occurs in transformer, current increases to a great value. It may be inrush current, internal fault or external fault. At starting of transformer, current goes to a higher value for a very few seconds. This is called as inrush current. Also in case of internal fault, current goes to a higher value for some time. So, the applied relay should trip only for internal fault and not for external fault or in the case of inrush current. That means, relay should discriminate between inrush current and internal fault. So here, this discrimination have done. To increase sensitivity of operation of digital differential relay for the protection of transformer. The operation of relay is simulated in MATLAB software and results are taken for different cases like magnetising inrush current, magnetising inrush current with adding load, three phase to ground fault at loaded transformer, line to ground external fault at loaded transformer, etc.

II. LITERATURE SURVEY

One of the most effective methods of protection for power transformers is the differential protection method by using Differential relay circuits. This scheme is based on the principle that the power input to the transformer under normal conditions is equal to the power output. By proper connection of the secondary of current transformers (C.T), under



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normal conditions, ideally no current will flow into the relay coil, i.e. the differential current is equal to zero. Whenever a fault occurs, within the protection zone, the current balance will no longer exist and the relay contacts will close and release a trip signal to cause a certain circuit breakers (CB) to activate in order to disconnect the faulty transformer from the grid. Hayward [3] presented in his paper a new type of relays using the principle of harmonic restraint, which is able to distinguish between the internal fault current and the magnetizing-inrush current by their difference in the waveform shape. This method is characterized by complicated circuits and consists of mechanical parts. Sachdev, Sidhu and Wood [4] presented a new digital algorithm to detect winding faults in single-phase and three-phase transformers. This algorithm is suitable whether or not it is possible to measure winding currents. A variety of operating conditions simulated on a computer were used to test the algorithm. Yabe [5] described a new method to discriminate internal fault current from inrush current by the sum of active power flowing into transformers from each terminal. To avoid the needless trip by magnetizing inrush current, the second harmonic component is commonly used for blocking Differential relay in power transformers. The proposed paper presents design software for Fourier Transform based logic technique to simulate the power transformer digital differential relay operation. This software improves and enhances the sensitivity of operation of the digital differential relay that protects power transformers by discriminating between the inrush current and fault current without blocking the relay during the energization of power Transformers, as well as avoiding tripping during the operation of tap changers.

III. PROPOSED METHODOLOGY AND DISCUSSION

This protection scheme is implemented on a transformer in MATLAB software. Current on both primary and secondary terminals of transformer is measured with the help of current measurement. Load is connected to the secondary side of a three phase power transformer. Circuit breakers CB1 and CB2 are connected in series on both the sides of the transformer to examine the switching effect on the protection system of transformer. In this scheme, currents have to go through two analysis processes. Amplitude comparison and harmonic content comparison. Harmonic content have compared between fundamental component and second harmonic component.

In amplitude comparison, both the terminal currents are compared. In normal condition, current on primary side is equal to the current on secondary side i.e. $I_1 = I_2$. But when fault occurs $I_1 \neq I_2$.

This scheme is implemented as follows:

- In the amplitude comparison, if the difference between primary and secondary terminal is not zero then the logic 1 will take place which will be the indication of an inrush current or internal fault. If the difference is not zero, logic 0 takes place which will be the indication of external fault.
- In harmonic comparator, if the percentage value of second harmonic amplitude is in the range of 0.3 to 0.6 of the fundamental component amplitude, then the logic 0 will occur, which will indicate inrush current. Otherwise, logic 1 takes place, which will indicate detection of internal or external fault.
- From above, if the logic received from both the cases is (1, 1), then it is the indication of internal fault. In this case, trip signal will be given.
- Also from above, we can see that logic (0, 1) indicates external fault, logic (1, 0) indicates inrush current and logic (0, 0) means the occurrence of inrush current or external fault. In these cases, trip signal will not be given.

The flow chart given below, explain the above description:

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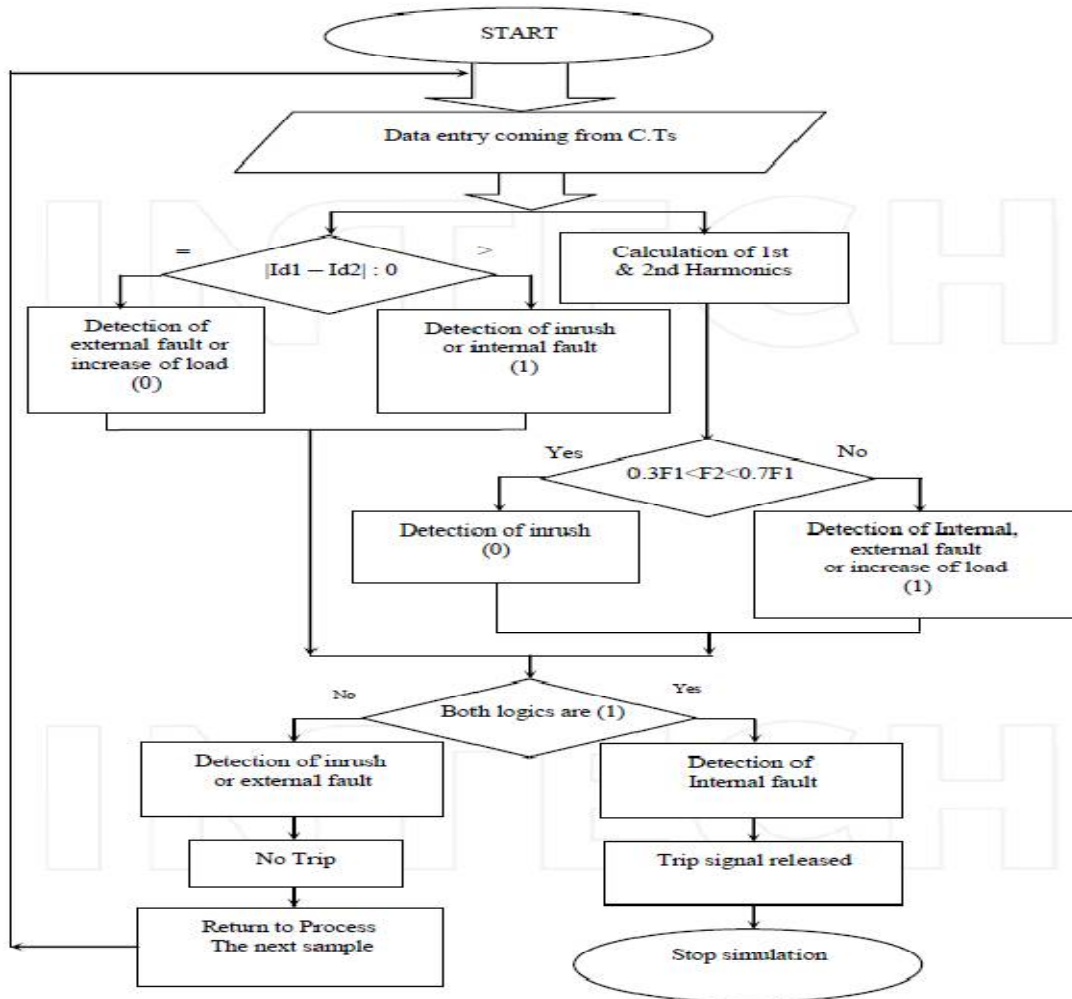


Figure 1: Flow chart of the Digital Differential Relay Scheme

Model:

For implication of above methodology, a model have made in software MATLAB Simulink. Figure below shows the model.

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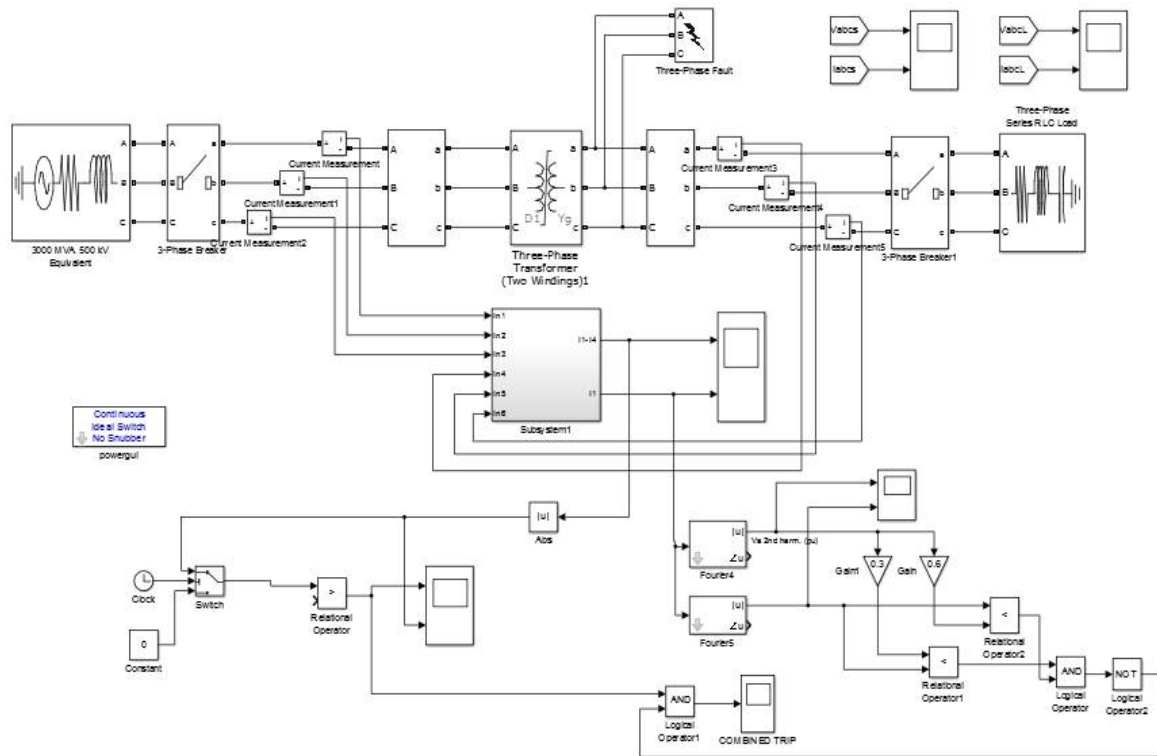


Figure 2: Model for the protection of a power transformer

IV. EXPERIMENTAL RESULTS

The results will be given for different cases as follows:

- Case 1: Magnetizing inrush current,
- Case 2: Magnetizing inrush with load,
- Case 3: Three phase to ground fault at loaded transformer,

Other cases of different types of faults and inrush currents such as single line to ground fault, line-to-line fault, line to line to ground fault and three phase fault in both cases loaded and unloaded transformer are also have given.

Case 1: Magnetizing inrush current:

In this case of simulation, when the primary side CB1 is closed at 0.1 sec, only the inrush current flows in the primary circuit of the power transformer and no current passes through the power transformer to the secondary side as shown in figure below. This current remains for less time. So, no trip signal is released in this case.

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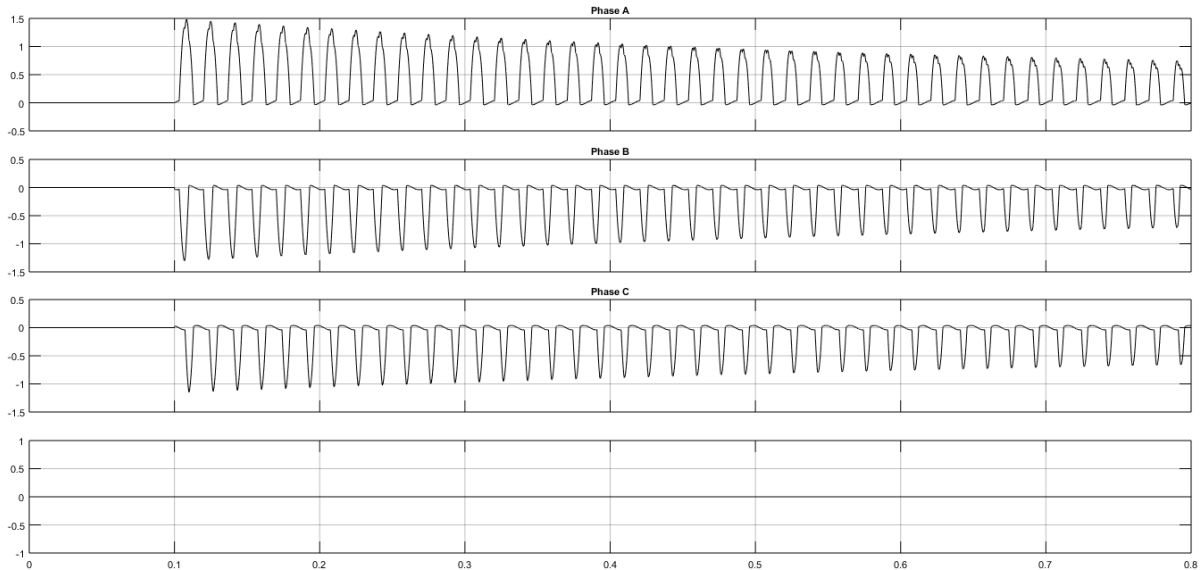


Figure 3: Inrush currents waveforms of the three phases at the primary side of the power transformer.

Case 2: Magnetizing inrush with adding load:

This test is carried out after the energization of the power transformer by switching ON the CB1 at 0.1sec and CB2 at 0.3 sec from the beginning of the simulation to see the effect of adding load on the accuracy. Therefore, a 500W resistive load is added to the system at 0.3 sec. Consequently, the inrush current disappeared and load current started to flow in the primary and secondary circuits of the transformer according to the transformation ratio of the power transformer as shown in Figure below. However, the amplitude of the output currents of the primary and secondary CTs are equal due to the proper selection of the transformation ratio of the primary and secondary CTs. Where, before the time 0.3 sec the differential current was equal to the inrush current, but after adding the load the differential current went to zero and the primary and secondary currents became equal.

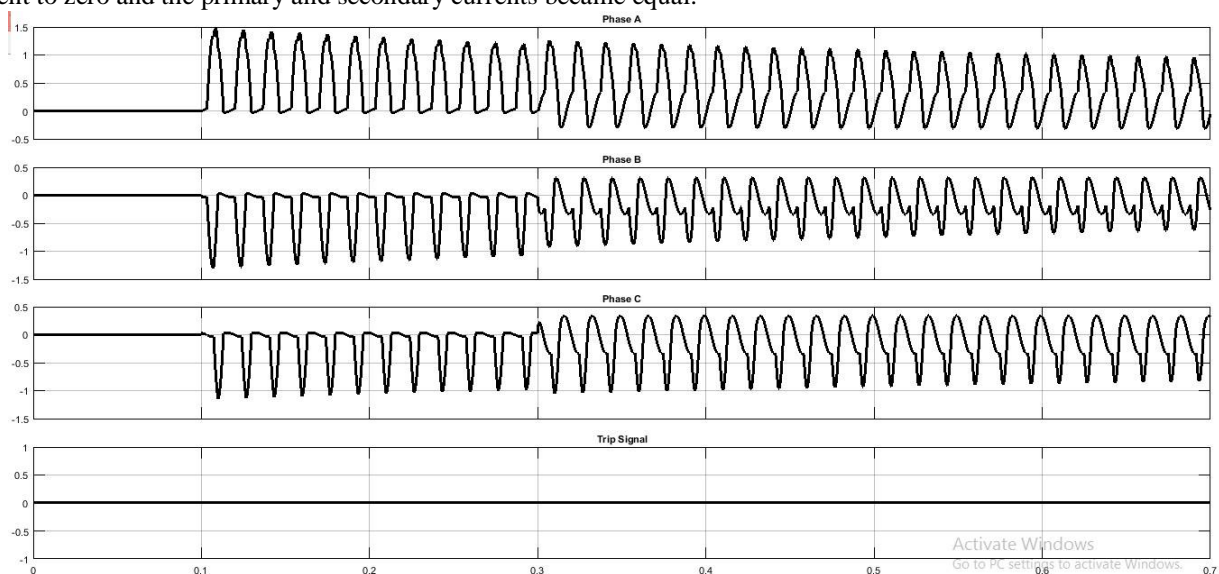


Figure 4: Normal load current starts flowing at 0.3sec

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Case 3: Three phase to ground fault at loaded transformer:

In this case, a three phase to ground fault is created to test the security of the algorithm. After the switching of CB1 at 0.1sec, an internal fault is created at 0.5 sec at the secondary side of the power transformer by connecting the three phases A, B and C of the secondary side of the power transformer to the ground. In this case, a significant increase of the primary current takes place due to the fault occurrence inside the protected zone at 0.5 sec. The relay detected this increase using the amplitude comparators and realized it as an internal fault. Consequently the transformer is isolated from the grid.

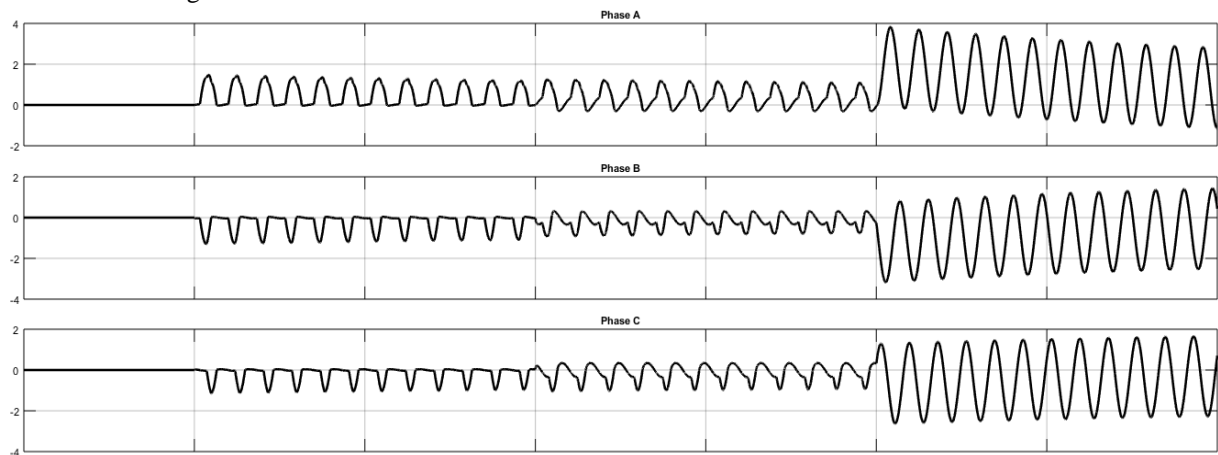


Figure 5: Increase of phase A, B & C currents due to the occurrence of the fault at 0.5 sec for loaded transformer

For this case, there will be trip command as follows.

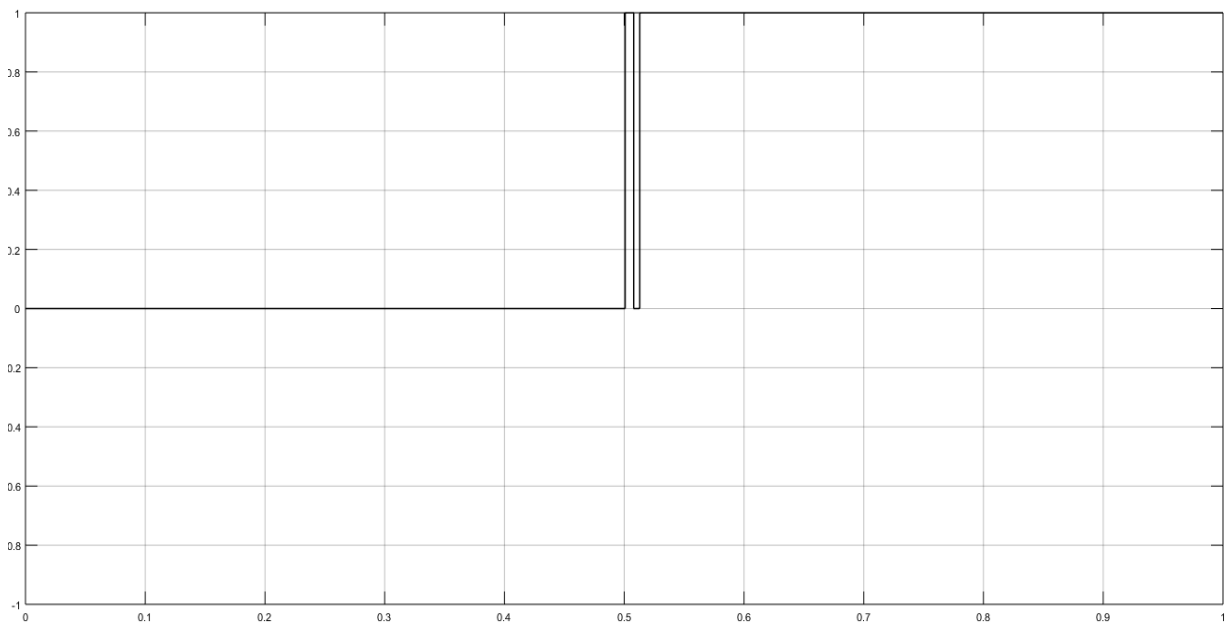


Figure 6: Trip command for three phase to ground fault



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V.CONCLUSION

The protection of transformers is very important because the transformer is a very important link in the power system. So, for this purpose, digital relays are used which are fast and accurate. Unit differential relaying scheme is applied for the protection of power transformer. From the work done, it can be concluded that we got satisfactory results. For case 1, when the transformer is energised at no load, inrush current flows in the primary winding which lasts for some time. So, there will be no trip command for this case. For case 2, when load is added at 0.3 sec, load current flows in the circuit. Till then inrush current flows in primary winding of transformer. For case 3, internal three phase to ground fault is created at 0.5 sec., so the fault current flows in all the phases which is high in magnitude.

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